Challenge #3: On the Cutting-edge

How many cuts are needed to reach 1nm?

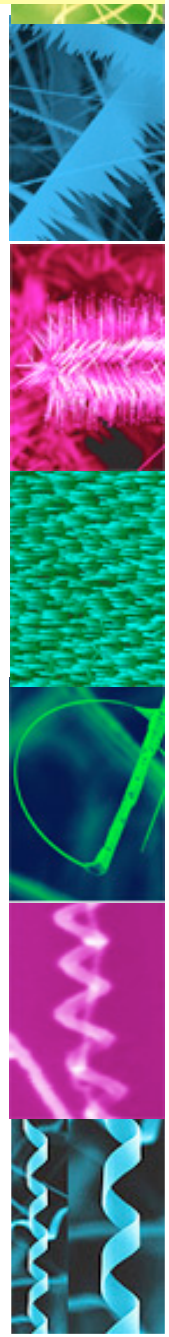
$$10^{-7}\ \text{cm} = 28\ \text{cm} \times 1/2^{x}$$

Need to solve for x: $1/2^{x} = 10^{-7}/28$

You can solve this in 2 ways:

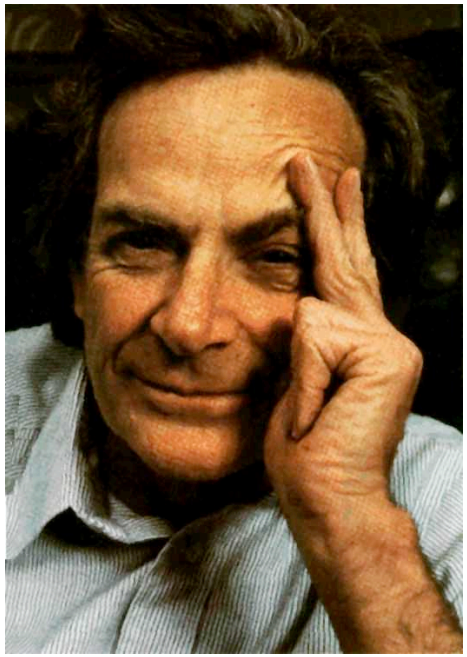
- exactly (using log and calculator) **x = 28**

- or by approximations ($28 = 32 = 2^5$ and $5 = 4 = 2^2$ ➔ $10^7 = 2^{21}$ or $5 = 8 = 2^3$ ➔ $10^7 = 2^{28}$) **x =26; x = 33**



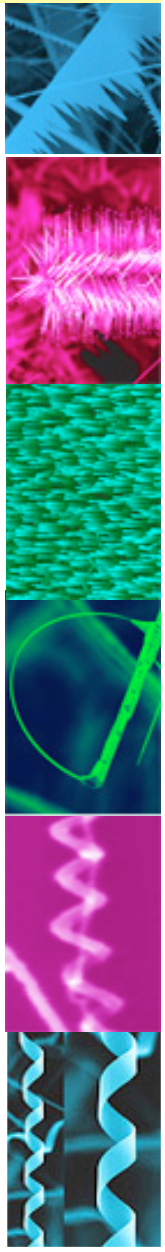
How did we get here?
Origin of Nanoscience

- New Tools! As tools change, what we can see and do changes.



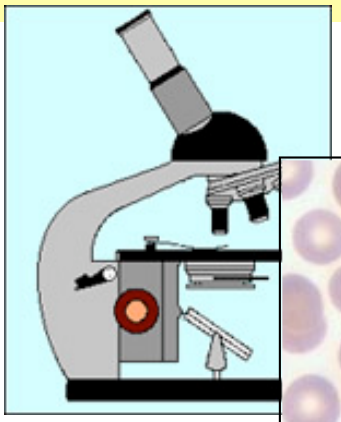
First theoretical introduction by
Richard Feynman
"***There's Plenty of Room at the Bottom***"
American Physical Society, 1959

- The key is to make use of the unique properties which arise because of the nanoscale.

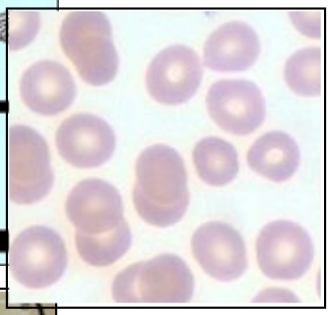


How to See Small Things

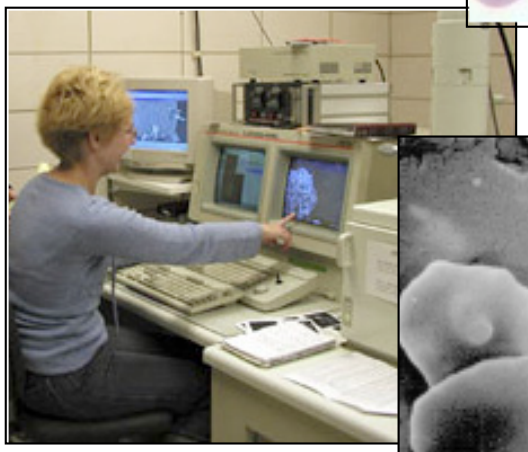
- The **naked eye** can see to about 20μm

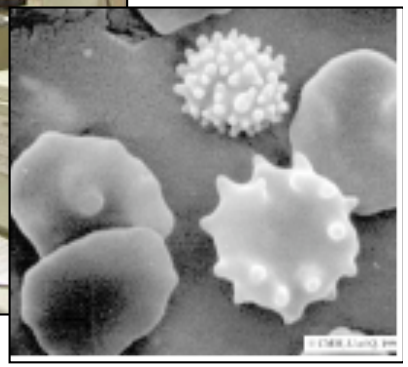


- **Light microscopes** let us see to about 1μm (bounce **light** off of surfaces to create images)

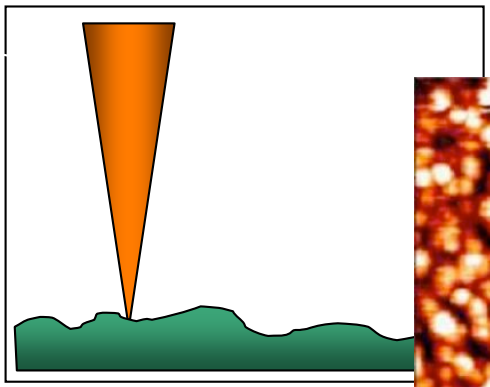


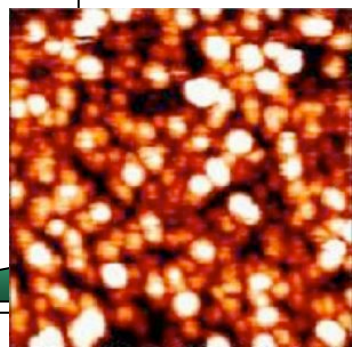
- **Scanning electron microscopes** (1930s) let us see objects as small as 10 nm (bounce **electrons** off of surfaces to create images)



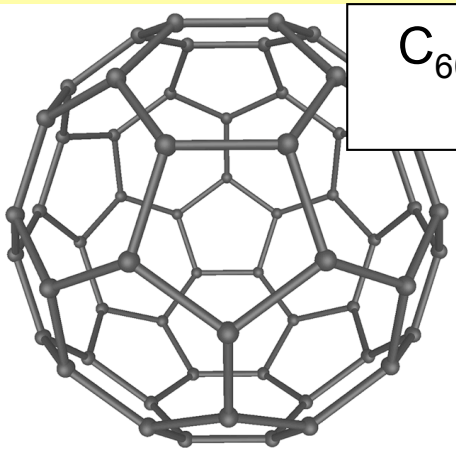


- **Scanning tunneling microscope** (1980) and **atomic force microscope** (1986) let us see and interact with the atomic structure (use the atom-to-atom interaction to map the surface)





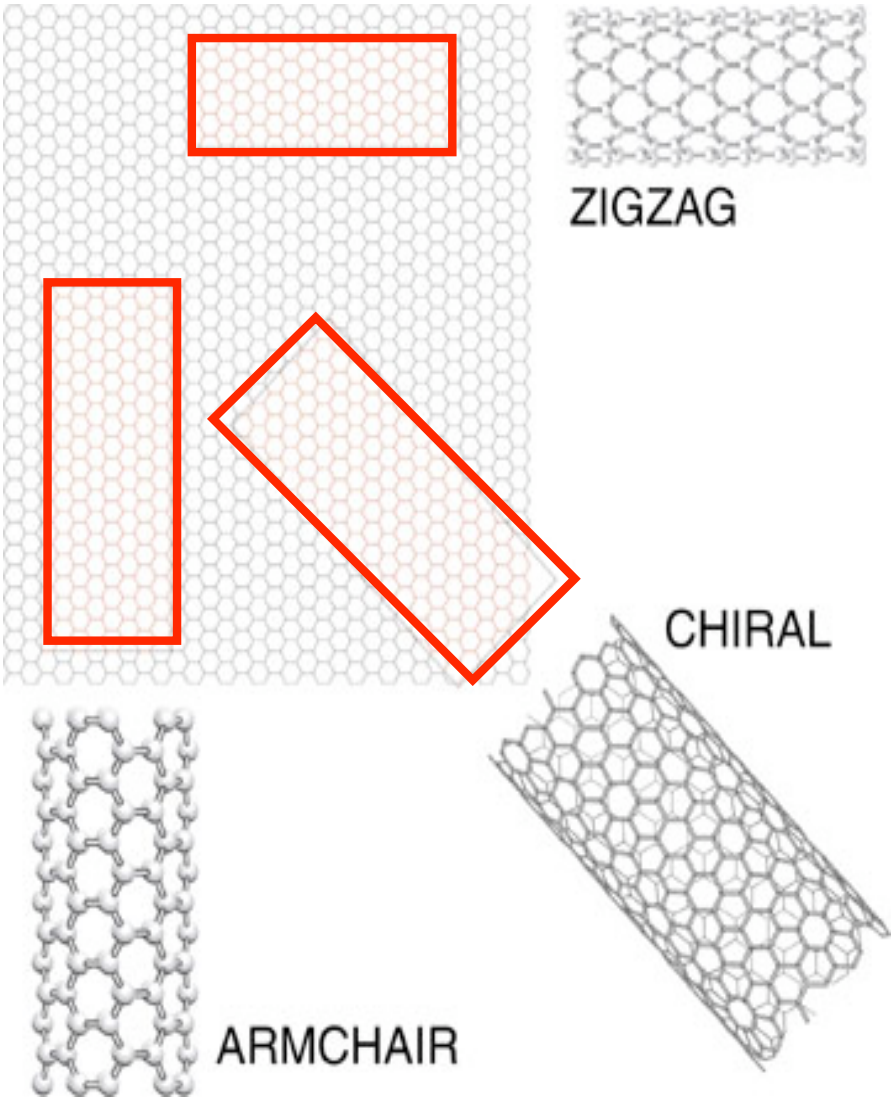
What did we see? New things!



C_{60} Bukyball or Fullerene

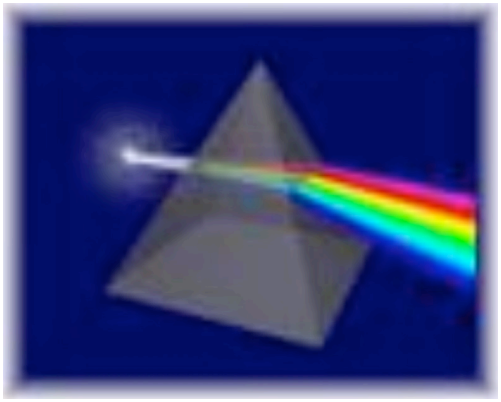
Fuller's American Pavillion, Monreal Expo '67

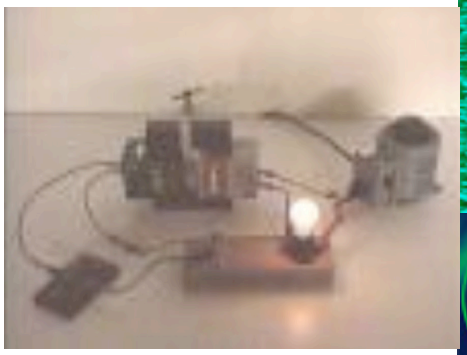
Graphene and Nanotubes



Size-Dependent Properties of Materials

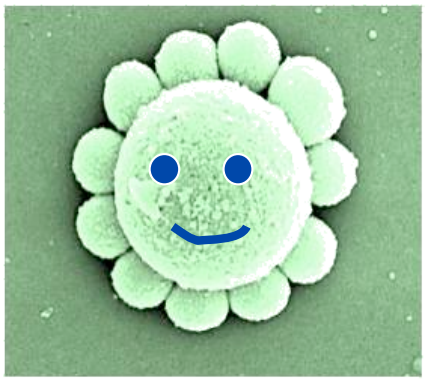
- Types of properties that describe how materials act under certain conditions:
  - Optical (e.g. color, transparency)
  - Electrical (e.g. conductivity)
  - Physical (e.g. hardness, melting point)
  - Chemical (e.g. reactivity, reaction rates)

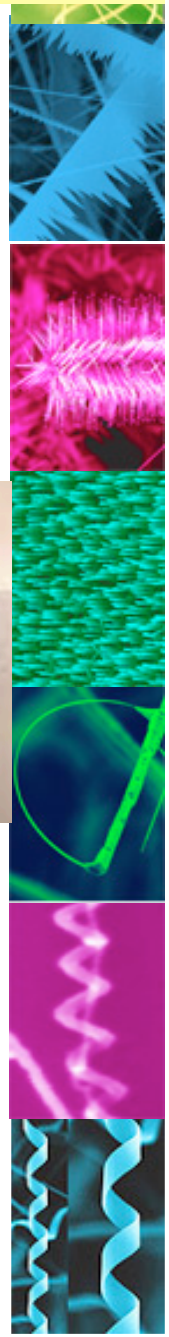




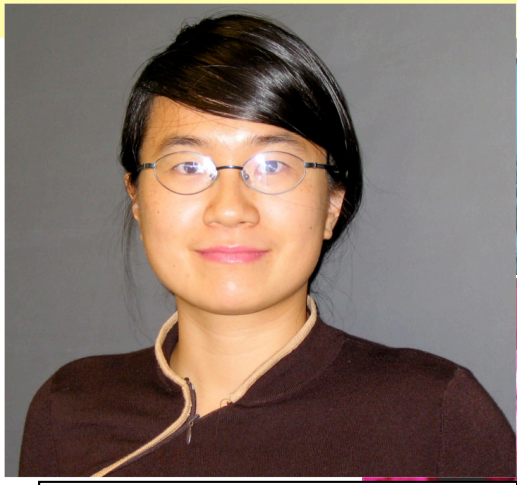
- At the nanoscale, properties change because different forces dominate at different scales.

- If you are a nanoparticle you are:
  - *Sticky* (intermolecular forces)
  - *Shaky* (thermal energy)
  - *Bumpy* (quantum effects)
  - *Gravity doesn't matter (really weak)*



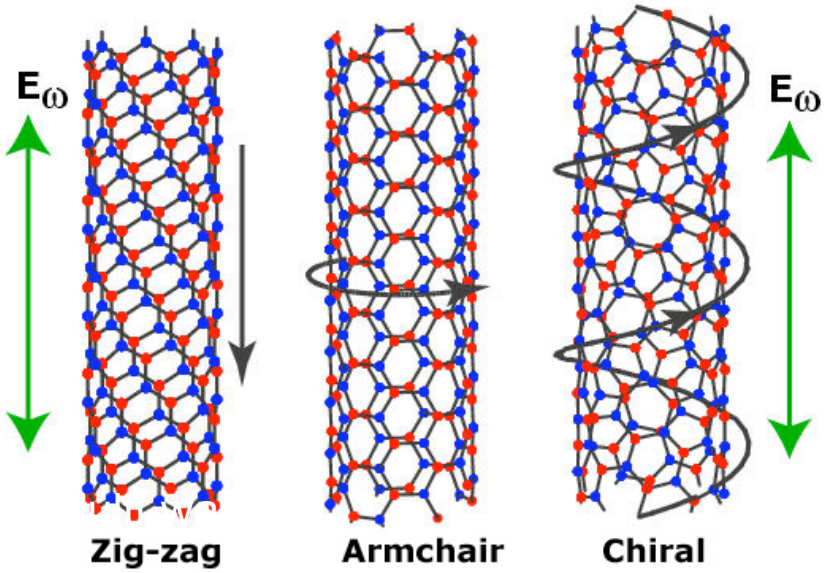


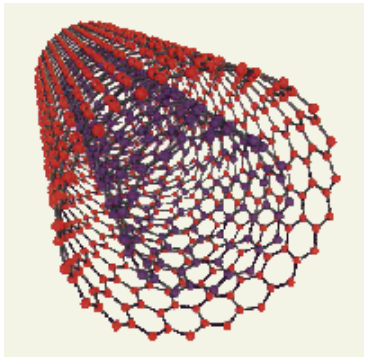
Electrical Properties: Conductivity of Nanotubes

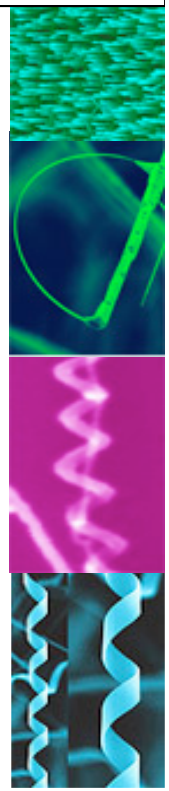


Jeanie Lau

- Because the mass of nanoscale objects is so small, gravity becomes negligible
- Nanotubes are long, thin cylinders of carbon
  - They are 100 times stronger than steel, very flexible, and have unique electrical properties
- Their electrical properties change with diameter, “twist”, and number of walls
  - They can be either conducting or semi-conducting







Energy Applications

Robert Haddon

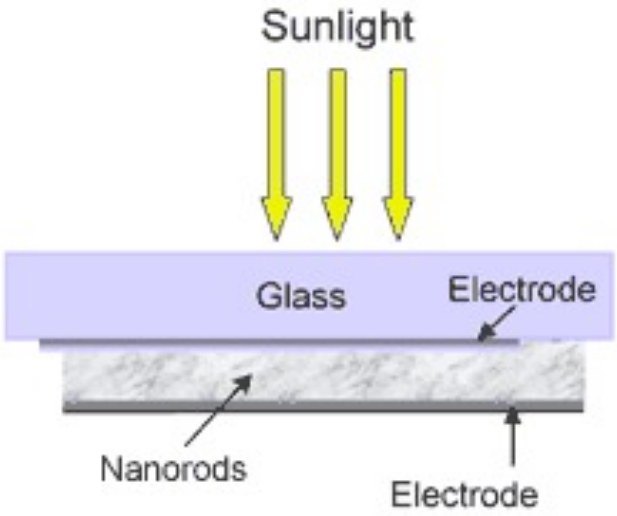
- Solid State Lighting (semiconductor)

Filament light bulbs waste about 90% of the input energy in heating.

If every light bulb in the USA is replaced with SSL technology, the total national electricity consumption would be reduced of 10%.
[DOE report, 2007]

Environment: Nano Solar Cells

- Solar cells are limited by their efficiency
- Nano solar cells mixed in plastic could be painted on buses, roofs, and clothing
  - Solar becomes a cheaper energy alternative!



Mihri Okzam

Nano solar cell: Inorganic nanorods embedded in semiconducting polymer, sandwiched between two electrodes